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SIR:

CERTIFIED TRANSLATION

I, Reiko IWAMOTO, am an official translator of the Japanese language into the English language and I hereby certify that the attached comprises an accurate translation into English of Japanese Application No. 2002-049163, filed on February 26, 2002.

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

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Date

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[Title of the Invention] LIQUID CRYSTAL DISPLAY AND
METHOD FOR MANUFACTURING THE SAME

[Claims]

[Claim 1] A liquid crystal display comprising a pair of substrates and a liquid crystal layer interposed between the substrates, the liquid crystal display having a reflective area and a transmissive area,

wherein at least one of the substrates is provided with a retardation film whose phase difference differs between the reflective area and the transmissive area.

[Claim 2] A liquid crystal display according to Claim 1, wherein the retardation film is provided on a surface of the substrate which faces the liquid crystal layer.

[Claim 3] A liquid crystal display according to Claim 1, wherein the retardation film is provided only in the reflective area.

[Claim 4] A liquid crystal display according to Claim 1, wherein the retardation film comprises a $\lambda/4$ layer.

[Claim 5] A liquid crystal display according to Claim 4, wherein the retardation film comprises the $\lambda/4$ layer and a retardation layer which compensates for chromatic dispersion which occurs at the $\lambda/4$ layer.

[Claim 6] A liquid crystal display according to Claim 5, wherein the retardation layer comprises a $\lambda/2$ layer.

[Claim 7] A liquid crystal display according to Claim 1, wherein the liquid crystal layer has a phase difference of $\lambda/4$ in the reflective area and a phase difference of $\lambda/2$ in the transmissive area when no voltage is applied or when a voltage is applied.

[Claim 8] A liquid crystal display according to Claim 1, wherein the retardation film is composed of a liquid crystal polymer.

[Claim 9] A liquid crystal display according to Claim 8, wherein the liquid crystal polymer is obtained by curing an ultraviolet-curable liquid crystal monomer in a nematic phase.

[Claim 10] A liquid crystal display according to Claim 1, wherein at least one of the substrates is provided with color filters and the phase difference of the retardation film is determined in accordance with the wavelength of each color filter.

[Claim 11] A liquid crystal display according to Claim 10, wherein the retardation film has a phase difference of $\lambda/4$ in accordance with the wavelength of each color filter.

[Claim 12] A liquid crystal display according to Claim 1, wherein the phase difference of the retardation film in the transmissive area cancels a residual phase difference which occurs when a sufficient voltage is applied to the liquid crystal layer.

[Claim 13] A method for manufacturing a liquid crystal display which has a pair of substrates and a liquid crystal layer interposed between the substrates and which has a reflective area and a transmissive area, the method comprising the steps of:

forming a retardation film on at least one of the substrates; and

patterning the retardation film such that the retardation film remains at least in the reflective area and the phase difference of the retardation film differs between the reflective area and the transmissive area.

[Claim 14] A method for manufacturing a liquid crystal display according to Claim 13, wherein the retardation film is patterned such that the retardation film remains only in the reflective area.

[Claim 15] A method for manufacturing a liquid crystal display according to Claim 13, wherein an alignment film is formed on at least one of the substrates and the retardation film is formed on the alignment film.

[Claim 16] A method for manufacturing a liquid crystal display according to Claim 15, wherein the retardation film is composed of a liquid crystal polymer.

[Claim 17] A method for manufacturing a liquid crystal display according to Claim 16, wherein the liquid crystal polymer is obtained by curing an ultraviolet-curable liquid

crystal monomer in a nematic phase.

[Claim 18] A method for manufacturing a liquid crystal display according to Claim 13, wherein the step of patterning the retardation film comprises an exposure process and a development process.

[Claim 19] A liquid crystal display comprising a pair of substrates and a liquid crystal layer interposed between the substrates, the liquid crystal display having a reflective area and a transmissive area,

wherein at least one of the substrates is provided with a retardation film whose slow axis differs between the reflective area and the transmissive area.

[Claim 20] A liquid crystal display according to Claim 19, wherein the retardation film is provided on a surface of the substrate which faces the liquid crystal layer.

[Claim 21] A liquid crystal display according to Claim 19, wherein a polarizer is provided on at least one of the substrates and the slow axis of the retardation film in the transmissive area is parallel to the transmission axis or the absorption axis of the polarizer.

[Claim 22] A liquid crystal display according to Claim 19, wherein a polarizer is provided on at least one of the substrates and the retardation layer polarizes light incident from the liquid crystal layer in a direction parallel to the absorption axis of the polarizer in the

transmissive area when no voltage is applied or when a voltage is applied.

[Claim 23] A liquid crystal display according to Claim 19, wherein the retardation film comprises a $\lambda/4$ layer.

[Claim 24] A liquid crystal display according to Claim 23, wherein the retardation film comprises the $\lambda/4$ layer and a retardation layer which compensates for chromatic dispersion which occurs at the $\lambda/4$ layer.

[Claim 25] A liquid crystal display according to Claim 24, wherein the retardation layer comprises a $\lambda/2$ layer.

[Claim 26] A liquid crystal display according to Claim 19, wherein at least one of the substrates is provided with color filters and the phase difference of the retardation film is determined in accordance with the wavelength of each color filter.

[Claim 27] A liquid crystal display according to Claim 26, wherein the retardation film has a phase difference of $\lambda/4$ in accordance with the wavelength of each color filter.

[Claim 28] A liquid crystal display according to Claim 19, wherein the liquid crystal layer has a phase difference of $\lambda/4$, where λ is the wavelength of light, in the reflective area and a phase difference of $\lambda/2$ in the transmissive area when no voltage is applied or when a voltage is applied.

[Claim 29] A liquid crystal display according to Claim 19, wherein the retardation film is composed of a liquid crystal

polymer.

[Claim 30] A liquid crystal display according to Claim 29, wherein the liquid crystal polymer is obtained by curing an ultraviolet-curable liquid crystal monomer in a nematic phase.

[Claim 31] A method for manufacturing a liquid crystal display which has a pair of substrates and a liquid crystal layer interposed between the substrates and which has a reflective area and a transmissive area, the method comprising the step of:

forming a retardation film whose slow axis is different between the reflective area and the transmissive area on at least one of the substrates.

[Claim 32] A method for manufacturing a liquid crystal display according to Claim 31, wherein the retardation film is composed of a liquid crystal polymer.

[Claim 33] A method for manufacturing a liquid crystal display according to Claim 32, wherein the liquid crystal polymer is obtained by curing an ultraviolet-curable liquid crystal monomer in a nematic phase.

[Claim 34] A method for manufacturing a liquid crystal display according to Claim 31, wherein the retardation film is formed by forming an alignment film by mask rubbing such that the alignment direction of the alignment film differs between the reflective area and the transmissive area, and

applying a liquid crystal polymer or an ultraviolet-curable liquid crystal monomer in a nematic phase on the alignment film.

[Claim 35] A method for manufacturing a liquid crystal display according to Claim 31, wherein the retardation film is formed by forming an alignment film by photoalignment such that the alignment direction of the alignment film differs between the reflective area and the transmissive area, and applying a liquid crystal polymer or an ultraviolet-curable liquid crystal monomer in a nematic phase on the alignment film.

[Detailed Description of the Invention]

[0001]

[Technical Field of the Invention]

The present invention relates to a transfective liquid crystal display having features of both reflective and transmissive displays and a method for manufacturing the transfective liquid crystal display.

[0002]

[Description of the Related Art]

In general, transmissive liquid crystal displays using backlights for displaying images have been mainly used as displays for personal computers. Recently, however, there have been increasing demands for displays for mobile electronic devices such as personal digital assistants

(PDAs) and mobile phones, and reflective liquid crystal displays which consume less power than the transmissive liquid crystal displays have been attracting attention. In the reflective liquid crystal displays, ambient light incident on and reflected by a reflector is used for displaying images, so no backlight is necessary and power consumption is low. Therefore, electronic devices including the reflective liquid crystal displays can be operated for a longer time compared to those including the transmissive liquid crystal displays.

[0003]

For the case in which the reflective liquid crystal displays, which normally use ambient light for displaying images, are used in dark places, a construction has been proposed in which a front light is arranged on a display side, that is, on the front of a liquid crystal panel and light emitted from the front light is used for displaying images. However, when the front light is disposed on the display side of the panel, the reflectivity and the contrast decrease and the image quality degrades.

[0004]

In order to solve this problem, transflective liquid crystal displays in which a reflector has a transmissive area in a pixel area and which have features of both the reflective and transmissive liquid crystal displays have

been developed. In the transreflective liquid crystal displays, a backlight is arranged on a liquid crystal panel on the side opposite to the display side, so that sufficient visibility can be obtained in both dark and light places without degrading the image quality as a reflective display. Accordingly, high image quality can be obtained. The basic construction of the transreflective liquid crystal displays is disclosed in, for example, Japanese Unexamined Patent Application Publications Nos. 2000-29010 and 2000-35570.

[0005]

With reference to Fig. 14, in a known transreflective liquid crystal display 101, a reflective electrode 104 composed of a material with high reflectivity and a transparent electrode 105 composed of a material with high transmittance are provided on a main surface of a substrate 102, the reflective electrode 104 being laminated on the substrate 102 with an interlayer film 103 therebetween, and a $\lambda/4$ layer 106 and a polarizer 107 are laminated on the other main surface of the substrate 102 in that order. In addition, in the liquid crystal display 101, a counter electrode 107 is provided on a main surface of another substrate 108 on the side facing the substrate 102, and a $\lambda/4$ layer 110 and a polarizer 111 are laminated on the other main surface of the substrate 108 in that order. A liquid crystal layer 112 composed of a liquid crystal material is

interposed between the reflective electrode 104 and the counter electrode 109 and between the transparent electrode 105 and the counter electrode 109. Thus, the liquid crystal display 101 shown in Fig. 14 includes two retardation layers, one on the front and one on the back.

[0006]

In order to reliably suppress the influence of chromatic dispersion and improve the dark state display, the construction shown in Fig. 15 may also be used. In a liquid crystal display 201 shown in Fig. 15, a $\lambda/4$ layer 106 and a $\lambda/2$ layer 113 provided on a substrate 102 are used in combination with each other and a $\lambda/4$ layer 110 and a $\lambda/2$ layer 114 provided on a substrate 108 are used in combination with each other. Thus, four retardation layers are used in total.

[0007]

[Problems to be Solved by the Invention]

In the liquid crystal display 101 shown in Fig. 14, the $\lambda/4$ layer 110 which serves as a retardation layer is provided on the display side of the substrate 108 such that it covers the entire area of the substrate 108 in order to suppress the influence of chromatic dispersion and achieve reflective display. Therefore, although a retardation layer such as a $\lambda/4$ layer is not necessary for transmissive display, since the $\lambda/4$ layer 110 which is provided on the

display side for achieving reflective display covers the entire area of the substrate 108, the $\lambda/4$ layer 106 must be provided on the substrate 102 arranged on the back in order to compensate for the phase difference of the $\lambda/4$ layer 110. More specifically, since a retardation layer is provided on the display side for achieving reflective display even though it is not necessary for transmissive display, an additional retardation layer must be provided to compensate for the phase difference of the retardation layer arranged on the display side.

[0008]

Similarly, in the liquid crystal display shown in Fig. 15, two of the four retardation layers which are placed on the back are simply provided to compensate for the phase difference of the other two retardation layers used for reflective display, and are not necessary for transmissive display.

[0009]

As described above, in known transflective liquid crystal displays, the required number of retardation layers is large compared to the reflective liquid crystal displays and the transmissive liquid crystal displays. Accordingly, high costs are incurred and the cell thickness is large.

[0010]

Accordingly, in order to solve the above-described

problems, an object of the present invention is to provide a transfective liquid crystal display which requires only a small number of retardation layers to be disposed on, for example, the back and a method for manufacturing the liquid crystal display.

[0011]

[Means for Solving the Problems]

In order to attain the above-described object, according to the present invention, a liquid crystal display includes a pair of substrates and a liquid crystal layer interposed between the substrates and has a reflective area and a transmissive area, and at least one of the substrates is provided with a retardation film whose phase difference differs between the reflective area and the transmissive area.

[0012]

According to another aspect of the present invention, a method for manufacturing a liquid crystal display which has a pair of substrates and a liquid crystal layer interposed between the substrates and which has a reflective area and a transmissive area includes the steps of forming a retardation film on at least one of the substrates and patterning the retardation film such that the retardation film remains at least in the reflective area and the phase difference of the retardation film differs between the

reflective area and the transmissive area.

[0013]

According to the liquid crystal display having the above-described construction, the phase difference of the retardation film provided on one of the substrates differs between the reflective area and the transmissive area, and the retardation film, which is necessary for displaying images in the reflective area, does not function in the transmissive area. Accordingly, sufficient reflectivity can be obtained in the reflective area due to the function of the retardation film and transmissive display can be achieved in the transmissive area without providing an additional retardation layer to compensate for the phase difference of the retardation layer.

[0014]

According to another aspect of the present invention, a liquid crystal display includes a pair of substrates and a liquid crystal layer interposed between the substrates and has a reflective area and a transmissive area, and at least one of the substrates is provided with a retardation film whose slow axis differs between the reflective area and the transmissive area.

[0015]

In addition, according to another aspect of the present invention, a method for manufacturing a liquid crystal

display which has a pair of substrates and a liquid crystal layer interposed between the substrates and which has a reflective area and a transmissive area includes the step of forming a retardation film whose slow axis is different between the reflective area and the transmissive area on at least one of the substrates.

[0016]

According to the liquid crystal display having the above-described construction, the slow axis of the retardation film provided on one of the substrates differs between the reflective area and the transmissive area, and the retardation film, which is necessary for displaying images in the reflective area, does not function in the transmissive area. Accordingly, sufficient reflectivity can be obtained in the reflective area due to the function of the retardation film and transmissive display can be achieved in the transmissive area without providing an additional retardation layer to compensate for the phase difference of the retardation layer.

[0017]

In the known transfective liquid crystal displays, a circular polarizer can be obtained by combining a polarizer and a $\lambda/4$ layer obtained by a single rubbing process and an exposure process, and the optical construction can therefore be easily designed. However, as described above, a

relatively large number of retardation films are necessary and high costs are incurred. On the contrary, according to the present invention, retardation films necessary in the known construction can be omitted by providing a retardation layer whose phase difference differs between the transmissive area and the reflective area and optimizing the relationship between the rubbing direction of the retardation film and the transmission axis of the polarizer.

[0018]

[Description of the Embodiments]

Liquid crystal displays to which the present invention is applied and methods for manufacturing the liquid crystal displays will be described below with reference to the accompanying drawings.

[0019]

<First Embodiment>

A transreflective liquid crystal display according to a first embodiment of the present invention will be described below. The liquid crystal display according to the first embodiment is characterized in that the phase difference of a retardation layer is different between a reflective area and a transmissive area. The basic construction of the liquid crystal display according to the first embodiment will be described below with reference to Fig. 1.

[0020]

In a liquid crystal display 1 shown in Fig. 1, a reflective electrode 3 composed of a material with high reflectivity which defines a reflective area and a transparent electrode 4 composed of a material with high transmittance which defines a transmissive area are provided on a main surface of a substrate 2, and a polarizer 5 is provided on the other main surface of the substrate 2. In addition, another substrate 6 which receives ambient light is placed on the display side, and a reflective-area $\lambda/4$ layer 7 which serves as a retardation layer and covers the reflective area and a counter electrode 8 which covers both the reflective and transmissive areas are provided on a main surface of the substrate 6 which faces the substrate 2. In addition, a polarizer 9 is provided on the other main surface of the substrate 6. A liquid crystal layer 10 composed of a liquid crystal material is interposed between the substrate 2 and the substrate 6, and a backlight (not shown) for transmissive display is disposed on the outer side of the polarizer 5. The transmission axis of the polarizer 9 and that of the polarizer 5 are perpendicular to each other. In addition, the slow axis of the reflective-area $\lambda/4$ layer 7 which serves as the retardation layer is at an angle of 45° with respect to the transmission axis of the polarizer 9.

[0021]

In the liquid crystal display 1 according to the first embodiment, the reflective-area $\lambda/4$ layer 7 which serves as the retardation layer is provided only in the reflective area, and is not provided in the transmissive area. Accordingly, a phase difference is different between the reflective area and the transmissive area. More specifically, a phase difference necessary for reflective display is obtained due to the function of the reflective-area $\lambda/4$ layer 7 in the reflective area, whereas no phase difference occurs in the transmissive area. According to the above-described construction, transmissive display can be achieved without providing an additional $\lambda/4$ layer on the back to compensate for the phase difference of the reflective-area $\lambda/4$ layer 7 provided on the display side.

[0022]

The reflective-area $\lambda/4$ layer 7 which serves as the retardation layer may also be disposed on the outer side of the substrate 6. However, it is preferably disposed on the surface facing the liquid crystal layer 10, as shown in Fig. 1, so that the problem of parallax caused by the thickness of the substrate 6 can be reduced.

[0023]

The reflective-area $\lambda/4$ layer 7 which serves as the retardation layer is obtained by, for example, applying a liquid-crystal polymer to the substrate 6 after an alignment

process, such as rubbing, and forming a pattern such that the liquid-crystal polymer remains only in the reflective area. More specifically, a photosensitive liquid-crystal polymer is applied to the substrate 6 after the alignment process, and an exposure process and a development process are performed so as to obtain the retardation layer having a desired pattern. Alternatively, the retardation layer may also be obtained by applying an ultraviolet-curable liquid crystal monomer in a nematic phase to the substrate 6 or an alignment film and irradiating it with an ultraviolet light to grow a liquid-crystal polymer. The phase difference of the retardation layer can be arbitrarily adjusted by changing the thickness thereof. The retardation layer is not necessarily composed of a liquid-crystal polymer, and may also be composed of, for example, an oriented film.

[0024]

The operation of displaying an image on the liquid crystal display 1 shown in Fig. 1 will be described below with reference to Figs. 2 and 3. For convenience, the substrate 2 and the counter electrode 8 are omitted in Figs. 2 and 3. The phase difference of the liquid crystal layer 10 is adjusted to be $\lambda/4$, where λ is the wavelength of light, in the reflective area and $\lambda/2$ in the transmissive area when light passes through the liquid crystal layer 10 once while no voltage is applied thereto. When no voltage is applied,

the liquid-crystal orientation is approximately parallel to the substrates 2 and 6 and is at an angle of 45° with respect to the transmission axis of the polarizer 9.

[0025]

A case in which no voltage is applied to the liquid crystal layer 10 and the light state is obtained will be described below with reference to Fig. 2.

[0026]

In the reflective area, ambient light is incident from the outer side of the substrate 6 (from the display side) and passes through the polarizer 9, where it is linearly polarized in a direction parallel to the transmission axis of the polarizer 9. The linearly polarized light is converted into circularly polarized light as it passes through the reflective-area $\lambda/4$ layer 7, is converted into linearly polarized light by the liquid crystal layer 10, and reaches the reflective electrode 3. The linearly polarized light is reflected by the reflective electrode 3 so that the traveling direction thereof is reversed, and is converted into circularly polarized light as it passes through the liquid crystal layer 10 again. The circularly polarized light passes through the reflective-area $\lambda/4$ layer 7 again, where it is linearly polarized in the direction parallel to the transmission axis of the polarizer 9, and passes through the polarizer 9.

[0027]

In the transmissive area, light emitted from the backlight is incident from the outer side of the substrate 2 (from the back) and passes through the polarizer 5, where it is linearly polarized in a direction parallel to the transmission axis of the polarizer 5. The linearly polarized light passes through the liquid crystal layer 10 having the phase difference of $\lambda/2$, where it is linearly polarized in a direction perpendicular to the transmission axis of the polarizer 5, that is, in the direction parallel to the transmission axis of the polarizer 9, and passes through the polarizer 9.

[0028]

Next, a case in which a voltage is applied to the liquid crystal layer 10 and the dark state is obtained will be described below with reference to Fig. 3.

[0029]

In the reflective area, ambient light is incident from the display side and passes through the polarizer 9, where it is linearly polarized in the direction parallel to the transmission axis of the polarizer 9. The linearly polarized light is converted into circularly polarized light as it passes through the reflective-area $\lambda/4$ layer 7. The circularly polarized light passes through the liquid crystal layer 10 and reaches the reflective electrode 3 without

changing the polarization state thereof, and is reflected by the reflective electrode 3. When the circularly polarized light is reflected by the reflective electrode 3, the rotating direction thereof is reversed. The thus reflected circularly polarized light passes through the liquid crystal layer 10 again, is incident on the reflective-area $\lambda/4$ layer 7, where it is linearly polarized in a direction perpendicular to the transmission axis of the polarizer 9, and is absorbed by the polarizer 9.

[0030]

In the transmissive area, light emitted from the backlight is incident from the back and passes through the polarizer 5, where it is linearly polarized in the direction parallel to the transmission axis of the polarizer 5. The linearly polarized light passes through the liquid crystal layer 10 and reaches the polarizer 9 without changing the polarization state thereof, and is absorbed by the polarizer 9.

[0031]

As described above, the reflective- area $\lambda/4$ layer 7, which is necessary for the dark state display in the reflective area, is not provided in the transmissive area. Accordingly, sufficient reflectivity can be obtained in the reflective area due to the function of the reflective-area $\lambda/4$ layer 7 and transmissive display can be achieved in the

transmissive area without providing an additional retardation layer on the back to compensate for the phase difference of the retardation layer on the display side. Accordingly, high quality, high contrast images can be displayed in both reflective display and transmissive display. In addition, it is not necessary to provide an additional retardation layer on the back, so that the cell thickness can be reduced and costs can be reduced by the amount corresponding to the omitted retardation layer.

[0032]

In the above description, liquid-crystal molecules in the liquid crystal layer are oriented approximately perpendicular to the substrates when a voltage is applied, and the liquid crystal layer has a phase difference of $\lambda/4$ in the reflective area and $\lambda/2$ in the transmissive area when no voltage is applied. According to the present invention, however, the construction of the liquid crystal display may also be opposite. More specifically, the liquid crystal layer may also have a phase difference of $\lambda/4$ in the reflective area and $\lambda/2$ in the transmissive area when a voltage is applied.

[0033]

According to the present embodiment, the retardation layer is not limited to that having a single-layer structure consisting of the reflective-area $\lambda/4$ layer, and may also

have a two-layer structure consisting of a reflective-area $\lambda/4$ layer and an additional retardation layer which compensates for the chromatic dispersion of the reflective-area $\lambda/4$ layer. A case in which a $\lambda/2$ layer is provided as the retardation layer which compensates for the chromatic dispersion of the reflective-area $\lambda/4$ layer will be described below with reference to Fig. 4. In Fig. 4, components similar to those of the liquid crystal display 1 shown in Fig. 1 are denoted by the same reference numerals, and explanations thereof are thus omitted.

[0034]

In a liquid crystal display 21 according to this modification, a retardation layer having a two-layer structure consisting of a reflective-area $\lambda/2$ layer 22 and a reflective-area $\lambda/4$ layer 7 is provided in the reflective area, and no retardation layer is provided in the transmissive area.

[0035]

As described above, in the liquid crystal display 21, the retardation layer having a two-layer structure is provided in the reflective area. Accordingly, in addition to the effects obtained by the liquid crystal display 1 having the basic structure, light leakage caused by the chromatic dispersion in the dark state display can be eliminated over a wide wavelength range and the image

quality can be improved.

[0036]

In the above-described liquid crystal displays 1 and 21, the retardation layer is completely removed in the transmissive area. According to the present invention, however, a retardation layer whose phase difference is different from that of the retardation layer provided in the reflective area may also be provided in the transmissive area. A liquid crystal display according to this modification will be described below with reference to Fig. 5. In Fig. 5, components similar to those of the liquid crystal display 1 shown in Fig. 1 and those of the liquid crystal display 21 shown in Fig. 4 are denoted by the same reference numerals, and explanations thereof are thus omitted.

[0037]

A liquid crystal display 31 shown in Fig. 5 is different from the liquid crystal display 21 shown in Fig. 4 in that a transmissive-area retardation layer 32 is provided on a substrate 6 on the side facing a liquid crystal layer 10. The phase difference of the transmissive-area retardation layer 32 is determined by taking various characteristics of the liquid crystal layer 10 into account, and is preferably set such that a residual phase difference which occurs when sufficient voltage is applied to the

liquid crystal layer 10 can be canceled.

[0038]

Accordingly, in the liquid crystal display 31, in addition to the effects obtained by the above-described liquid crystal display 21, the darkness in the dark state display can be increased in the transmissive area and the image quality can be improved.

[0039]

In this modification, a retardation layer having a two-layer structure consisting of a reflective-area $\lambda/4$ layer 7 and a reflective-area $\lambda/2$ layer 22 is provided in the reflective area. However, the effects obtained by providing the transmissive-area retardation layer 32 can also be obtained when a retardation layer having a single-layer structure is provided in the reflective area.

[0040]

According to the present embodiment, the liquid crystal display may also be a full-color liquid crystal display 41, as shown in Fig. 6.

[0041]

In the liquid crystal display 41 shown in Fig. 6, color filters 42R, 42G, and 42B corresponding to red, green, and blue dots, respectively, are provided on a substrate 6 on the side facing a liquid crystal layer 10. In addition, reflective-area $\lambda/4$ layers 7R, 7G, and 7B which serve as

retardation layers are provided on the color filters 42R, 42G, and 42B, respectively, at regions corresponding to the reflective area. In addition, a counter electrode 8 is provided on these reflective-area retardation layers with an overcoat layer 43 therebetween.

[0042]

In the liquid crystal display 41 according to this modification, the thicknesses of the reflective-area $\lambda/4$ layers 7R, 7G, and 7B which serve as the retardation layers are adjusted in accordance with the transmission wavelengths of the color filters 42R, 42G, and 42B, respectively, so that each retardation layer has a phase difference of $\lambda/4$. Accordingly, the influence of the chromatic dispersion of each color can be reduced and the image quality can be improved.

[0043]

In the above descriptions, liquid crystal displays in which the retardation layer is provided on the substrate arranged on the display side are explained. However, the present invention is not limited to this, and is applicable as long as a retardation layer whose phase difference is different between the reflective area and the transmissive area is provided on at least one of the substrates. For example, the present invention may also be applied to a case where the retardation layer is provided on the substrate

adjacent to the backlight.

[0044]

<Second Embodiment>

Next, a transreflective liquid crystal display according to a second embodiment of the present invention will be described below. The liquid crystal display according to the second embodiment is characterized in that the slow axis of a retardation layer is different between a reflective area and a transmissive area. The basic construction of the liquid crystal display according to the second embodiment will be described below with reference to Fig. 7. In Fig. 7, components similar to those of the liquid crystal display 1 shown in Fig. 1 are denoted by the same reference numerals, and explanations thereof are thus omitted.

[0045]

In a liquid crystal display 51 shown in Fig. 7, a reflective electrode 3 composed of a material with high reflectivity which defines a reflective area and a transparent electrode 4 composed of a material with high transmittance which defines a transmissive area are provided on a main surface of a substrate 2. The reflective electrode 3 is laminated on the substrate 2 with an interlayer film 52 therebetween, and an alignment film 53 is laminated on the reflective electrode 3 and the transparent electrode 4. In addition, a polarizer 5 is provided on the

other main surface of the substrate 2. Another substrate 6 which receives ambient light is placed on the display side, and a reflective-area $\lambda/4$ layer 7 which serves as a retardation layer and covers the reflective area and a transmissive-area $\lambda/4$ layer 55 which also serves as a retardation layer and covers the transmissive area are provided on a main surface of the substrate 6 which faces the substrate 2 with an alignment film 54 therebetween. In addition, a counter electrode 8 which covers both the reflective area and the transmissive area is provided on the reflective-area $\lambda/4$ layer 7 and the transmissive-area $\lambda/4$ layer 55, and an alignment film 56 is provided on the counter electrode 8. In addition, a polarizer 9 is provided on the other main surface of the substrate 6. A liquid crystal layer 10 composed of a liquid crystal material is interposed between the substrate 2 and the substrate 6, and a backlight (not shown) for transmissive display is disposed on the outer side the polarizer 5. The transmission axis of the polarizer 9 and that of the polarizer 5 are perpendicular to each other. In addition, the slow axis of the reflective-area $\lambda/4$ layer 7 which serves as the retardation layer in the reflective area is at an angle of 45° with respect to the transmission axis of the polarizer 9.

[0046]

The slow axis of the transmissive-area $\lambda/4$ layer 55

which serves as the retardation layer in the transmissive area and that of the reflective-area $\lambda/4$ layer 7 which serves as the retardation layer in the reflective area extend in different directions. More specifically, the slow axis of the transmissive-area $\lambda/4$ layer 55 is parallel to the transmission axis of the polarizer 9 provided on the substrate 6.

[0047]

In the liquid crystal display 51 according to the second embodiment, a retardation layer which covers the entire area of the substrate 6 is subjected to multi-domain alignment so that the slow axis of the reflective-area $\lambda/4$ layer 7 and that of the transmissive-area $\lambda/4$ layer 55 are different from each other. Thus, only the reflective-area $\lambda/4$ layer 7 functions as a retardation layer. More specifically, the slow axis of the transmissive-area $\lambda/4$ layer 55 is parallel to the transmission axis of the polarizer 9 provided on the front, so that the transmissive-area $\lambda/4$ layer 55 does not have an effective phase difference. According to the above-described construction, transmissive display can be achieved without providing an additional $\lambda/4$ layer on the back to compensate for the phase difference of the reflective-area $\lambda/4$ layer 7.

[0048]

The reflective-area $\lambda/4$ layer 7 and the transmissive-

area $\lambda/4$ layer 55 which serve as the retardation layers may also be disposed on the outer side of the substrate 6. However, they are preferably disposed on the surface facing the liquid crystal layer 10, as shown in Fig. 7, so that the problem of parallax caused by the thickness of the substrate 6 can be reduced.

[0049]

The reflective-area $\lambda/4$ layer 7 and the transmissive-area $\lambda/4$ layer 55 which serve as the retardation layers are obtained by, for example, applying a liquid-crystal polymer to the substrate 6 after an alignment process, such as rubbing. More specifically, a photosensitive liquid-crystal polymer is applied to the substrate 6 after the alignment process, and an exposure process and a development process are performed so as to obtain the retardation layers having a desired pattern. Alternatively, the retardation layers may also be obtained by applying an ultraviolet-curable liquid crystal monomer in a nematic phase to the substrate 6 or the alignment film and irradiating it with an ultraviolet light to grow a liquid-crystal polymer. In addition, the reflective-area $\lambda/4$ layer 7 and the transmissive-area $\lambda/4$ layer 55 may also be obtained by subjecting a film formed by applying a liquid-crystal polymer to a photoalignment process. The phase differences of the retardation layers can be arbitrarily adjusted by changing the thicknesses

thereof. The retardation layers may also be composed of, for example, oriented films.

[0050]

In the present embodiment, the slow axis of the retardation layer in the transmissive area may be parallel to any one of the transmission axis and the absorption axis of the polarizer on the display side and the transmission axis and the absorption axis of the polarizer on the back as long as the retardation layer in the transmissive area does not have an effective phase difference.

[0051]

The operation of displaying an image on the liquid crystal display 51 shown in Fig. 7 will be described below with reference to Figs. 8 and 9. For convenience, the substrate 2, the counter electrode 8, and the alignment films are omitted in Figs. 8 and 9. In addition, the thickness of the liquid crystal layer 10 is adjusted such that the phase difference is $\lambda/4$ in the reflective area and $\lambda/2$ in the transmissive area when light passes through the liquid crystal layer 10 once while no voltage is applied thereto. When no voltage is applied, the liquid-crystal orientation is approximately parallel to the substrates 2 and 6 and is at an angle of 45° with respect to the transmission axis of the polarizer 9.

[0052]

A case in which no voltage is applied to the liquid crystal layer 10 and the light state is obtained will be described below with reference to Fig. 8.

[0053]

In the reflective area, ambient light is incident from the display side and passes through the polarizer 9, where it is linearly polarized in a direction parallel to the transmission axis of the polarizer 9. The linearly polarized light is converted into circularly polarized light as it passes through the reflective-area $\lambda/4$ layer 7, is converted into linearly polarized light by the liquid crystal layer 10, and reaches the reflective electrode 3. The linearly polarized light is reflected by the reflective electrode 3 so that the traveling direction thereof is reversed, and is converted into circularly polarized light as it passes through the liquid crystal layer 10 again. The circularly polarized light passes through the reflective-area $\lambda/4$ layer 7 again, where it is linearly polarized in the direction parallel to the transmission axis of the polarizer 9, and passes through the polarizer 9.

[0054]

In the transmissive area, light emitted from the backlight is incident from the back and passes through the polarizer 5, where it is linearly polarized in a direction parallel to the transmission axis of the polarizer 5. The

linearly polarized light passes through the liquid crystal layer 10 having the phase difference of $\lambda/2$, where it is linearly polarized in a direction perpendicular to the transmission axis of the polarizer 5, that is, in the direction parallel to the transmission axis of the polarizer 9, passes through the transmissive-area $\lambda/4$ layer 55 without changing the polarization state thereof, and passes through the polarizer 9.

[0055]

Next, a case in which a voltage is applied to the liquid crystal layer 10 and the dark state is obtained will be described below with reference to Fig. 9.

[0056]

In the reflective area, ambient light is incident from the display side and passes through the polarizer 9, where it is linearly polarized in the direction parallel to the transmission axis of the polarizer 9. The linearly polarized light is converted into circularly polarized light as it passes through the reflective-area $\lambda/4$ layer 7. The circularly polarized light passes through the liquid crystal layer 10 and reaches the reflective electrode 3 without changing the polarization state thereof, and is reflected by the reflective electrode 3. When the circularly polarized light is reflected by the reflective electrode 3, the rotating direction thereof is reversed. The thus reflected

circularly polarized light passes through the liquid crystal layer 10 again, is incident on the reflective-area $\lambda/4$ layer 7, where it is linearly polarized in a direction perpendicular to the transmission axis of the polarizer 9, and is absorbed by the polarizer 9.

[0057]

In the transmissive area, light emitted from the backlight is incident from the back and passes through the polarizer 5, where it is linearly polarized in the direction parallel to the transmission axis of the polarizer 5. The linearly polarized light passes through the liquid crystal layer 10 and the transmissive-area $\lambda/4$ layer 55 and reaches the polarizer 9 without changing the polarization state thereof, and is absorbed by the polarizer 9.

[0058]

As described above, in the liquid crystal display 51, the slow axis of the transmissive-area $\lambda/4$ layer 55 is parallel to the transmission axis of the polarizer 9, so that the transmissive-area $\lambda/4$ layer 55 does not function as a retardation layer. Accordingly, sufficient reflectivity can be obtained in the reflective area due to the function of the reflective-area $\lambda/4$ layer 7 and transmissive display can be achieved in the transmissive area without providing an additional retardation layer on the back to compensate for the phase difference of the retardation layer on the

display side. Accordingly, high quality, high contrast images can be displayed in both reflective display and transmissive display. In addition, it is not necessary to provide an additional retardation layer on the back, so that the cell thickness can be reduced and costs can be reduced by the amount corresponding to the omitted retardation layer.

[0059]

In the above description, liquid-crystal molecules in the liquid crystal layer are oriented approximately perpendicular to the substrates when a voltage is applied, and the liquid crystal layer has a phase difference of $\lambda/4$ in the reflective area and $\lambda/2$ in the transmissive area when no voltage is applied. According to the present invention, however, the construction of the liquid crystal display may also be opposite. More specifically, the liquid crystal layer may also have a phase difference of $\lambda/4$ in the reflective area and $\lambda/2$ in the transmissive area when a voltage is applied.

[0060]

According to the present embodiment, the retardation layers are not limited to those having a single-layer construction consisting of the reflective-area $\lambda/4$ layer 7 and the transmissive-area $\lambda/4$ layer 55, and may also have a two-layer structure, as shown in Fig. 10. In Fig. 10, components similar to those of the liquid crystal display 51

shown in Fig. 7 are denoted by the same reference numerals, and explanations thereof are thus omitted.

[0061]

In a liquid crystal display 61 according to this modification, a reflective-area $\lambda/4$ layer 7 and a transmissive-area $\lambda/4$ layer 55 which serve as retardation layers, a reflective-area $\lambda/2$ layer 22 which compensates for the chromatic dispersion of the reflective-area $\lambda/4$ layer 7, and a transmissive-area $\lambda/2$ layer 62 are provided on a substrate 6 on the side facing a liquid crystal layer 10. The slow axis of the retardation layer in the transmissive area is different from that of the retardation layer in the reflective area. More specifically, the transmissive-area $\lambda/2$ layer 62 and the reflective-area $\lambda/4$ layer 7 function as a $\lambda/2$ layer and a $\lambda/4$ layer, respectively, whereas the transmissive-area $\lambda/2$ layer 62 and the transmissive-area $\lambda/4$ layer 55 do not function as retardation layers since the slow axes thereof are parallel to, for example, the transmission axis of a polarizer 9. The retardation layers having the two-layer structure are obtained by, for example, the following processes. That is, first, the reflective-area $\lambda/2$ layer 22 and the transmissive-area $\lambda/2$ layer 62 are formed by applying a liquid-crystal polymer or an ultraviolet-curable liquid crystal monomer in a nematic phase to an alignment film 54 on the substrate 6 which is

subjected to multi-domain alignment in advance so that the alignment direction differs between the reflective area and the transmissive area. Then, an alignment film 63, which is subjected to multi-domain alignment so that the alignment direction differs between the reflective area and the transmissive area, is provided on the $\lambda/2$ layers. Then, the reflective-area $\lambda/4$ layer 7 and the transmissive-area $\lambda/4$ layer 55 are formed by applying a liquid-crystal polymer or an ultraviolet-curable liquid crystal monomer in a nematic phase to alignment film 63. The multi-domain alignment may, of course, also be achieved by a photoalignment process.

[0062]

As described above, the retardation layers have a two-layer structure, and the slow axis of the retardation layer in the reflective area is different from that of the retardation layer in the transmissive area. Thus, according to the liquid crystal display 61, in addition to the effects obtained by the liquid crystal display 51 having the basic structure of the present embodiment, light leakage caused by the chromatic dispersion in the dark state display can be eliminated over a wide wavelength range and the image quality can be improved.

[0063]

The present invention is not limited to liquid crystal displays in which the retardation layers are provided on the

substrate 6 arranged on the display side, and may also be applied to liquid crystal displays in which the retardation layers are provided on the substrate 2 adjacent to the backlight. For example, in a liquid crystal display 71 shown in Fig. 11, a reflective electrode 3 and a transparent electrode 4 are provided on a substrate 2 arranged on the back, and a reflective-area $\lambda/4$ layer 7 and a transmissive-area $\lambda/4$ layer 55 which serve as retardation layers are laminated on the reflective electrode 3 and the transparent electrode 4, respectively.

[0064]

Although the reflective-area $\lambda/4$ layer 7 functions as a retardation layer, the transmissive-area $\lambda/4$ layer 55 does not function as a retardation layer since the slow axis thereof is parallel to, for example, the transmission axis of the polarizer 9. When the retardation layers are provided on the substrate adjacent to the backlight, as in the liquid crystal display 71 shown in Fig. 11, sufficient reflectivity can be obtained in the reflective area due to the function of the reflective-area $\lambda/4$ layer 7 and transmissive display can be achieved in the transmissive area without providing an additional retardation layer on the display side to compensate for the phase difference of the retardation layer on the back. Accordingly, similar to the above-described liquid crystal displays, high quality,

high contrast images can be displayed in both reflective display and transmissive display. In addition, it is not necessary to provide an additional retardation layer on the back, so that the cell thickness can be reduced and costs can be reduced by the amount corresponding to the omitted retardation layer.

[0065]

In addition, according to the present embodiment, the liquid crystal display may also be a full-color liquid crystal display 81 as shown in Fig. 12.

[0066]

In the liquid crystal display 81, color filters 42R, 42G, and 42B corresponding to red, green, and blue dots, respectively, are provided on a substrate 6 on the side facing a liquid crystal layer 10. In addition, a reflective-area $\lambda/4$ layer 7R and a transmissive-area $\lambda/4$ layer 55R, a reflective-area $\lambda/4$ layer 7G and a transmissive-area $\lambda/4$ layer 55G, and a reflective-area $\lambda/4$ layer 7B and a transmissive-area $\lambda/4$ layer 55B, which serve as reflective-area retardation layers, are provided on the color filters 42R, 42G, and 42B, respectively. In addition, a counter electrode 8 is provided on these retardation layers with an overcoat layer 43 therebetween.

[0067]

The slow axis is different between the reflective area

and the transmissive area in each pair of the reflective-area $\lambda/4$ layer 7R and the transmissive-area $\lambda/4$ layer 55R, the reflective-area $\lambda/4$ layer 7G and the transmissive-area $\lambda/4$ layer 55G, and the reflective-area $\lambda/4$ layer 7B and the transmissive-area $\lambda/4$ layer 55B, so that the retardation layers in the transmissive area do not function. Therefore, similar to the above-described liquid crystal displays, it is not necessary to provide additional retardation layers on the back to compensate for the phase difference of the retardation layers used for reflective display and the number of retardation layers can be reduced.

[0068]

In the liquid crystal display 81 according to this modification, the thicknesses of the reflective-area $\lambda/4$ layer 7R and the transmissive-area $\lambda/4$ layer 55R, the reflective-area $\lambda/4$ layer 7G and the transmissive-area $\lambda/4$ layer 55G, and the reflective-area $\lambda/4$ layer 7B and the transmissive-area $\lambda/4$ layer 55B, which serve as reflective-area retardation layers, are adjusted in accordance with the transmission wavelengths of the color filters 42R, 42G, and 42B, respectively, so that each retardation layer has a phase difference of $\lambda/4$. Accordingly, the influence of the chromatic dispersion of each color can be reduced and the image quality can be improved.

[0069]

The present invention is not limited to the case where the slow axis of the retardation layer in the transmissive area is completely parallel or perpendicular to the transmission axis of the polarizer arranged on the front or back so that the retardation layer in the transmission area does not function at all, and the slow axis of the retardation layer in the transmissive area may also be slightly shifted. For example, the slow axis of the retardation layer in the transmissive area may also have a phase difference which is determined by taking various characteristics of the liquid crystal layer into account. In such a case, preferably, the displacement of the slow axis of the retardation layer in the transmissive area is set such that the phase difference in the transmissive area cancels a residual phase difference in the liquid crystal layer which occurs when sufficient voltage is applied to the liquid crystal layer. Accordingly, compared to the case in which the retardation layer in the transmissive area does not function at all, the darkness in the dark state display can be increased in the transmissive area and the image quality can be improved.

[0070]

According to the second embodiment, the slow axis of the retardation layer in the transmissive area is parallel to the transmission axis of the polarizer on the front.

However, the effects of the present invention may also be obtained when the slow axis of the retardation layer in the transmissive area is parallel to the transmission axis of the polarizer on the back.

[0071]

[Examples]

Examples in which the present invention is applied will be described below in conjunction with experiment results. Examples 1 to 5 correspond to the first embodiment, and Examples 6 to 10 correspond to the second embodiment.

[0072]

<Example 1>

In Example 1, a full-color liquid crystal panel whose optical construction was the same as that of the liquid crystal display 1 shown in Fig. 1 was manufactured.

[0073]

First, a substrate to be arranged on the back having thin film transistors (TFTs) for active-matrix driving of a liquid crystal layer was manufactured. A method for forming the TFTs will be described below with reference to Fig. 13.

[0074]

A borosilicate glass (Corning 7059 produced by Corning Incorporated) was used as a substrate 2. First, a gate electrode 91 composed of Mo, MoW, etc., a gate insulator 92, and amorphous silicon were successively deposited on the

substrate 2 and patterned, and the amorphous silicon was crystallized by annealing it with an excimer laser so as to form a semiconductor thin film 93. Then, P and B were doped into the semiconductor thin film 93 on both sides of the gate electrode 91, so that n-channel and p-channel TFTs were obtained. Then, a first interlayer insulator 94 composed of SiO_2 was formed on the substrate 2 so as to cover the TFTs.

[0075]

Then, holes were formed in the first interlayer insulator 94 by, for example, etching, at positions corresponding to a source and a drain of the semiconductor thin film 93, and signal lines 95 composed of Al were formed in a predetermined shape by patterning.

[0076]

Next, a second interlayer insulator 96 having both a function as a scattering layer for causing scattered reflection and a function as an interlayer insulator was formed on the substrate 2 so as to cover the TFTs and the signal lines 95. Then, a transparent electrode 4 composed of indium tin oxide (ITO) was formed on the second interlayer insulator 96 at regions corresponding to the transmissive area and a reflective electrode 3 composed of Ag was formed on the second interlayer insulator 96 at regions corresponding to the reflective area. Accordingly, the substrate 2 is arranged on the side adjacent to the

backlight was manufactured as shown in Fig. 13.

[0077]

Then, a black matrix composed of Cr was formed on a counter substrate, and red, green, and blue (RGB) filters were formed on the counter substrate in a predetermined pattern. Then, an alignment film was formed on the color filters by applying polyimide to the color filters by printing and rubbing it.

[0078]

Then, an ultraviolet-curable liquid crystal monomer (RMM 34 produced by Merck Ltd.) was spin-coated on the alignment film and was subjected to an exposure process and a development process, so that a reflective-area $\lambda/4$ layer which served as a retardation layer was formed only in the reflective area and no retardation layer was formed in the transmissive area. Since this ultraviolet-curable liquid crystal monomer cannot be sufficiently polymerized when oxygen exists, the above-described processes were performed in N_2 atmosphere. In addition, since the birefringence Δn of RMM 34 is 0.145, the thickness of the retardation layer formed by spin coating was set to 950 nm. Accordingly, the retardation was within the range of 135 nm to 140 nm. After the retardation layer was formed, a counter electrode was formed by sputtering ITO.

[0079]

Then, normal cell processes were performed. More specifically, an alignment film was formed on the counter electrode by applying polyimide to the counter electrode by printing and rubbing it.

[0080]

The rubbing direction of the alignment film adjacent to the retardation layer was the same as the orientation of the liquid-crystal polymer on the side facing the retardation layer. In addition, the rubbing direction of the alignment film on the substrate having the TFTs was set antiparallel to the rubbing direction of the alignment film adjacent to the retardation layer.

[0081]

The substrate having the TFTs and the counter substrate having the retardation layer were assembled together by normal processes, and a liquid crystal panel whose optical construction was the same as that of the liquid crystal display shown in Fig. 1 and which was provided with the color filters was thus obtained. Then, it was experimentally confirmed that high-contrast images could be displayed by using this panel.

[0082]

<Example 2>

In Example 2, a full-color liquid crystal panel whose optical construction was the same as that of the liquid

crystal display 21 shown in Fig. 4 was manufactured.

[0083]

First, a substrate having TFTs similar to that shown in Fig. 13 was formed by processes similar to those of Example 1.

[0084]

Then, color filters were formed on a counter substrate by processes similar to those of Example 1, and an alignment film was formed on the color filters by applying polyimide to the color filters by printing and rubbing it.

[0085]

Then, an ultraviolet-curable liquid crystal monomer was applied to the alignment film such that the $\lambda/2$ condition was satisfied, and was patterned such that a retardation layer was formed only in the reflective area. Accordingly, a reflective-area $\lambda/2$ layer which served as a retardation layer was formed.

[0086]

Next, polyimide was applied by printing and was rubbed in a direction at an angle of 60° with respect to the rubbing direction of the above-described alignment film. Then, an ultraviolet-curable liquid crystal monomer was applied such that the $\lambda/4$ condition was satisfied, and was patterned such that a retardation layer was formed only in the reflective area. Accordingly, a reflective-area $\lambda/4$

layer which served as a retardation layer was formed. After the retardation layer having a two-layer structure consisting of the reflective-area $\lambda/2$ layer and the reflective-area $\lambda/4$ layer was formed, a counter electrode was formed by sputtering ITO.

[0087]

Then, normal cell processes were performed. More specifically, an alignment film was formed on the counter electrode by applying polyimide to the counter electrode by printing and rubbing it. The rubbing process was performed such that the orientation of the liquid-crystal layer is between $\lambda/2$ and $\lambda/4$.

[0088]

The substrate having the TFTs and the counter substrate having the retardation layer were assembled together by normal processes, and a liquid crystal panel whose optical construction was the same as that of the liquid crystal display shown in Fig. 4 and which was provided with the color filters was thus obtained. Then, it was experimentally confirmed that high-contrast images could be displayed by using this panel.

[0089]

<Example 3>

In Example 3, a full-color liquid crystal panel whose optical construction was the same as that of the liquid

crystal display 31 shown in Fig. 5 was manufactured.

[0090]

First, a substrate having TFTs similar to that shown in Fig. 13 was formed by processes similar to those of Example 1.

[0091]

Then, color filters were formed on a counter substrate by processes similar to those of Example 1, and an alignment film was formed on the color filters by applying polyimide to the color filters by printing and rubbing it.

[0092]

Next, a retardation layer consisting of a reflective-area $\lambda/2$ layer and a reflective-area $\lambda/4$ layer was formed only in the reflective area by processes similar to those of Example 2.

[0093]

Next, polyimide was applied by printing and was rubbed in a direction at an angle of 90° with respect to the center line between the slow axes of the reflective-area $\lambda/2$ layer and the reflective-area $\lambda/4$ layer. Then, a transmissive-area retardation layer for canceling a residual phase difference which occurred when a voltage was applied to the liquid crystal layer was formed only in the transmissive area. The transmissive-area retardation layer had a phase difference of 30 nm, which was the same as the residual

phase difference which occurred when a voltage was applied to the liquid crystal layer.

[0094]

After the retardation layer in the reflective area and the transmissive-area retardation layer were formed, a counter electrode was formed by sputtering ITO.

[0095]

Then, normal cell processes were performed. More specifically, an alignment film was formed on the counter electrode by applying polyimide to the counter electrode by printing and rubbing it.

[0096]

The substrate 2 having the TFTs and the counter substrate 6 having the retardation layer were assembled together by normal processes, and a liquid crystal panel whose optical construction was the same as that of the liquid crystal display shown in Fig. 1 and which was provided with the color filters was thus obtained. Then, it was experimentally confirmed that the dark state display in transmissive display could be improved compared to the liquid crystal panel of Example 1 and high-contrast images could be displayed by using this panel.

[0097]

<Example 4>

In Example 4, a full-color liquid crystal panel whose

optical construction was the same as that of the liquid crystal display 41 shown in Fig. 6 was manufactured.

[0098]

First, a substrate having TFTs similar to that shown in Fig. 13 was formed by processes similar to those of Example 1.

[0099]

Then, color filters were formed on a counter substrate by processes similar to those of Example 1, and an alignment film was formed on the color filters by applying polyimide to the color filters by printing and rubbing it.

[0100]

Then, an ultraviolet-curable liquid crystal monomer was spin-coated on the alignment film and was subjected to an exposure process and a development process, so that reflective-area $\lambda/4$ layers which served as retardation layers were formed only in the reflective area and no retardation layer was formed in the transmissive area.

[0101]

The thickness of each retardation layer was set in accordance with a phase difference of its corresponding pixel. More specifically, the thickness of the retardation layer for a green pixel was set to 950 nm as in Example 1. In addition, the thickness of the retardation layer for a blue pixel was set to 730 nm since the birefringence Δn was

about 0.155 according to the retardation at the blue pixel, and the thickness of the retardation layer for a red pixel was set to 1200 nm since the birefringence Δn was about 0.135 according to the retardation at the red pixel.

[0102]

After the retardation layers were formed, a counter electrode was formed by sputtering ITO.

[0103]

Then, normal cell processes were performed. More specifically, an alignment film was formed on the counter electrode by applying polyimide to the counter electrode by printing and rubbing it.

[0104]

The substrate having the TFTs and the counter substrate having the retardation layers were assembled together by normal processes, and a liquid crystal panel whose optical construction was the same as that of the liquid crystal display shown in Fig. 1 and which was provided with the color filters was thus obtained. Then, it was experimentally confirmed that the dark state display could be improved compared to the liquid crystal panel of Example 1 and high-contrast images could be displayed by using this panel.

[0105]

<Example 5>

In Example 5, a liquid crystal panel was manufactured in which a retardation layer was formed on a substrate having TFTs arranged adjacent to a backlight in a reflective area thereof.

[0106]

First, a substrate having TFTs similar to that shown in Fig. 13 was formed by processes similar to those of Example 1. Then, a reflective-area $\lambda/4$ layer which served as a retardation layer was formed on a reflective electrode provided on this substrate, and an ITO electrode was formed on the reflective-area $\lambda/4$ layer by sputtering.

[0107]

In addition, a counter electrode was formed on a counter substrate by sputtering ITO, and no retardation layer was formed on this substrate. Then, an alignment film was formed on the counter electrode by applying polyimide to the counter electrode by printing and rubbing it.

[0108]

The substrate having the TFTs and the retardation layer and the counter substrate having the counter electrode were assembled together by normal processes, and a liquid crystal panel was thus obtained. Then, it was experimentally confirmed that, similar to Example 1, high-contrast images could be displayed in transmissive display by using this panel.

[0109]

<Example 6>

In Example 6, a full-color liquid crystal panel whose optical construction was the same as that of the liquid crystal display 51 shown in Fig. 7 was manufactured.

[0110]

First, a substrate having TFTs similar to that shown in Fig. 13 was formed by processes similar to those of Example 1.

[0111]

Then, a black matrix composed of Cr was formed on a counter substrate, and red, green, and blue (RGB) filters were formed on the counter substrate in a predetermined pattern. Then, an alignment film was formed on the color filters by applying polyimide to the color filters by printing and rubbing it.

[0112]

In the rubbing process, mask rubbing was performed in which the alignment film was first rubbed in a predetermined direction while one of a reflective area and a transmissive area was masked with resist using photolithography techniques, and then rubbed in another direction while the other area was masked with resist. The rubbing direction in the reflective area was at an angle of 45° with respect to the transmission axis of a polarizer to be arranged on the

front, and that in the transmissive area was parallel to the transmission axis of the polarizer on the front.

[0113]

Then, an ultraviolet-curable liquid crystal monomer was spin-coated on the alignment film and was subjected to an exposure process, so that a $\lambda/4$ layer which served as a retardation layer was formed. The liquid-crystal polymer was aligned along the rubbing direction of the alignment film provided under it. Accordingly, although the retardation layer functioned as a $\lambda/4$ layer in the reflective area, an effective phase difference did not occur in the transmissive area since the slow axis thereof was parallel to the transmission axis of the polarizer on the front. RMM 34 produced by Merck Ltd. was used as the ultraviolet-curable liquid crystal monomer. Since this ultraviolet-curable liquid crystal monomer cannot be sufficiently polymerized when oxygen exists, the above-described processes were performed in N_2 atmosphere. In addition, since the birefringence Δn of RMM 34 is 0.145, the thickness of the retardation layer formed by spin coating was set to 950 nm. Accordingly, the retardation was within the range of 135 nm to 140 nm. After the retardation layer was formed, a counter electrode was formed by sputtering ITO.

[0114]

Then, normal cell processes were performed. More

specifically, an alignment film was formed on the counter electrode by applying polyimide to the counter electrode by printing and rubbing it.

[0115]

The rubbing direction of the alignment film adjacent to the retardation layer was the same as the orientation of the liquid-crystal polymer on the side facing the retardation layer. In addition, the rubbing direction of the alignment film on the substrate having the TFTs was set antiparallel to the rubbing direction of the alignment film adjacent to the retardation layer.

[0116]

A liquid-crystal material was injected and sealed between the substrate having the TFTs and the counter substrate having the retardation layer and the polarizer was laminated on the front such that the slow axis of the retardation layer in the transmissive area was parallel to the transmission axis of the polarizer. Accordingly, a liquid crystal panel whose optical construction was the same as that of the liquid crystal display shown in Fig. 7 and which was provided with the color filters was thus obtained. Then, it was experimentally confirmed that high-contrast images could be displayed in both reflective display and transmissive display by using this panel.

[0117]

<Example 7>

In Example 7, a full-color liquid crystal panel whose optical construction was the same as that of the liquid crystal display 61 shown in Fig. 10 was manufactured.

[0118]

First, a substrate having TFTs similar to that shown in Fig. 13 was formed by processes similar to those of Example 1.

[0119]

Then, a black matrix composed of Cr was formed on a counter substrate, and red, green, and blue (RGB) filters were formed on the counter substrate in a predetermined pattern. Then, similar to Example 7, an alignment film was formed on the color filters by applying polyimide to the color filters by printing and rubbing it.

[0120]

Then, an ultraviolet-curable liquid crystal monomer was spin-coated on the alignment film and was subjected to an exposure process, so that a $\lambda/2$ layer which served as a retardation layer was formed. The ultraviolet-curable liquid crystal monomer was aligned along the rubbing direction of the alignment film provided under it. Accordingly, although the retardation layer functioned as a $\lambda/2$ layer in the reflective area, an effective phase difference did not occur in the transmissive area since the

slow axis of the retardation layer was parallel to the transmission axis of the polarizer on the front.

[0121]

Then, polyimide was applied to the $\lambda/2$ layer by printing and was rubbed in a direction at an angle of 60° with respect to the rubbing direction of the above-described alignment film in the reflective area and in a direction parallel to the transmission axis of the polarizer on the front in the transmissive area, so that an alignment film was formed on the $\lambda/2$ layer.

[0122]

Then, an ultraviolet-curable liquid crystal monomer was applied to this alignment film and was subjected to an exposure process, so that a $\lambda/4$ layer which served as a retardation layer was formed. The ultraviolet-curable liquid crystal monomer was aligned along the rubbing direction of the alignment film provided under it. Accordingly, although the retardation layer functioned as a $\lambda/4$ layer in the reflective area, an effective phase difference did not occur in the transmissive area since the slow axis of the retardation layer was parallel to the transmission axis of the polarizer on the front.

[0123]

Then, a counter electrode was formed on the $\lambda/4$ layer by sputtering ITO.

[0124]

Then, normal cell processes were performed. More specifically, an alignment film was formed on the counter electrode by applying polyimide to the counter electrode by printing and rubbing it. The rubbing process was performed such that the orientation of the liquid-crystal layer is between $\lambda/2$ and $\lambda/4$.

[0125]

The substrate having the TFTs and the counter substrate having the retardation layer were assembled together by normal processes, and the polarizers were laminated on the outer sides of the substrates. The polarizer on the front was arranged such that the transmission axis thereof was at an angle of 15° with respect to the slow axis of the reflective-area $\lambda/2$ layer, and the polarizer on the back was arranged such that the transmission axis thereof was at an angle of 90° with respect to the transmission axis of the polarizer on the front. Accordingly, the slow axis of the reflective-area $\lambda/2$ layer was parallel to the transmission axis of the polarizer on the front.

[0126]

Accordingly, a liquid crystal panel whose optical construction was the same as that of the liquid crystal display shown in Fig. 10 and which was provided with the color filters was thus obtained. Then, it was

experimentally confirmed that high-contrast images could be displayed in both reflective display and transmissive display by using this panel.

[0127]

<Example 8>

In Example 8, a liquid crystal panel whose optical construction was the same as that of the liquid crystal display 71 shown in Fig. 11 was manufactured.

[0128]

First, a substrate having TFTs similar to that shown in Fig. 13 was formed by processes similar to those of Example 1. Then, an $\lambda/4$ layer which served as a retardation layer was formed on a reflective electrode and a transparent electrode provided on the substrate by applying an ultraviolet-curable liquid crystal monomer. In this process, in order for the retardation layer to function as a $\lambda/4$ layer only in the reflective area, an underlayer thereof was subjected to mask rubbing such that the rubbing direction differs between the reflective area and the transmissive area. Then, an alignment film was formed on the retardation layer by applying polyimide to the retardation layer by printing.

[0129]

In addition, a counter electrode was formed on a counter substrate by sputtering ITO, and no retardation

layer was formed on this substrate. Then, an alignment film was formed on the counter electrode by applying polyimide to the counter electrode by printing and rubbing it.

[0130]

The substrate having the TFTs and the retardation layer and the counter substrate having the counter electrode were assembled together by normal processes, and a liquid crystal panel was thus obtained. Then, it was experimentally confirmed that, similar to Example 6, high-contrast images could be displayed in transmissive display by using this panel.

[0131]

<Example 9>

In Example 9, a liquid crystal display whose optical construction was the same as that of the liquid crystal display 81 shown in Fig. 12 was manufactured.

[0132]

First, a substrate having TFTs similar to that shown in Fig. 13 was formed by processes similar to those of Example 1.

[0133]

Then, a black matrix composed of Cr was formed on a counter substrate, and red, green, and blue (RGB) filters were formed on the counter substrate in a predetermined pattern. Then, similar to Example 6, an alignment film was

formed on the color filters by applying polyimide to the color filters by printing and rubbing it.

[0134]

Then, an ultraviolet-curable liquid crystal monomer was applied to the alignment film and was subjected to an exposure process so that $\lambda/4$ layers which served as retardation layers was formed. The thickness of each retardation layer was set in accordance with a phase difference of its corresponding pixel. More specifically, the thickness of the retardation layer for a green pixel was set to 950 nm as in Example 6. In addition, the thickness of the retardation layer for a blue pixel was set to 730 nm since the birefringence Δn was about 0.155 according to the retardation at the blue pixel, and the thickness of the retardation layer for a red pixel was set to 1200 nm since the birefringence Δn was about 0.135 according to the retardation at the red pixel.

[0135]

The ultraviolet-curable liquid crystal monomer was aligned along the rubbing direction of the alignment film provided under it. Accordingly, although the retardation layers functioned as a $\lambda/4$ layer in the reflective area, an effective phase difference did not occur in the transmissive area since the slow axes of the retardation layers were parallel to the transmission axis of the polarizer on the

front.

[0136]

After the retardation layers were formed, a counter electrode was formed by sputtering ITO.

[0137]

The substrate having the TFTs and the substrate having the retardation layer were assembled together by normal processes, and a liquid crystal panel whose optical construction was the same as that of the liquid crystal display 81 shown in Fig. 12 was thus obtained. Then, it was experimentally confirmed that the dark state display could be improved compared to the liquid crystal panel of Example 6 and high-contrast images could be displayed by using this panel.

[0138]

<Example 10>

In Example 10, a full-color liquid crystal panel was manufactured similarly to that of Example 7 except that multi-domain alignment of the retardation layer was achieved by a photoalignment process. In Example 7, an alignment film was formed by using a material produced by Vantico Inc.

[0139]

It was experimentally confirmed that, similar to Example 7, high-contrast images could be displayed in both reflective display and transmissive display by using this

panel.

[0140]

[Advantages]

As described above, according to the liquid crystal display and the manufacturing method thereof of the present invention, the phase difference of the retardation film provided on one of the substrates differs between the reflective area and the transmissive area, and the retardation film, which is necessary for displaying images in the reflective area, does not function in the transmissive area. Accordingly, sufficient reflectivity can be obtained in the reflective area due to the function of the retardation film and transmissive display can be achieved in the transmissive area without providing an additional retardation layer to compensate for the phase difference of the retardation layer. Accordingly, the present invention provides a transreflective liquid crystal display which requires only a small number of retardation films and has a small cell thickness, and which can be manufactured at low costs.

[0141]

In addition, according to the liquid crystal display and the manufacturing method thereof of the present invention, the slow axis of the retardation film provided on one of the substrates differs between the reflective area

and the transmissive area, and the retardation film, which is necessary for displaying images in the reflective area, does not function in the transmissive area. Accordingly, sufficient reflectivity can be obtained in the reflective area due to the function of the retardation film and transmissive display can be achieved in the transmissive area without providing an additional retardation layer to compensate for the phase difference of the retardation layer. Accordingly, the present invention provides a transreflective liquid crystal display which requires only a small number of retardation films and has a small cell thickness, and which can be manufactured at low costs. Accordingly, the present invention provides a transreflective liquid crystal display which requires only a small number of retardation films and has a small cell thickness, and which can be manufactured at low costs.

[Brief Description of the Drawings]

[Fig. 1]

Fig. 1 is a schematic sectional view showing the basic construction of a liquid crystal display according to a first embodiment of the present invention.

[Fig. 2]

Fig. 2 is an exploded perspective view showing the optical construction of the liquid crystal display shown in Fig. 1 when no voltage is applied.

[Fig. 3]

Fig. 3 is an exploded perspective view showing the optical construction of the liquid crystal display shown in Fig. 1 when a voltage is applied.

[Fig. 4]

Fig. 4 is a schematic sectional view showing a modification of the liquid crystal display according to the first embodiment.

[Fig. 5]

Fig. 5 is a schematic sectional view showing another modification of the liquid crystal display according to the first embodiment.

[Fig. 6]

Fig. 6 is a schematic sectional view showing another modification of the liquid crystal display according to the first embodiment.

[Fig. 7]

Fig. 7 is a schematic sectional view showing the basic construction of a liquid crystal display according to a second embodiment of the present invention.

[Fig. 8]

Fig. 8 is an exploded perspective view showing the optical construction of the liquid crystal display shown in Fig. 7 when no voltage is applied.

[Fig. 9]

Fig. 9 is an exploded perspective view showing the optical construction of the liquid crystal display shown in Fig. 7 when a voltage is applied.

[Fig. 10]

Fig. 10 is a schematic sectional view showing a modification of the liquid crystal display according to the second embodiment.

[Fig. 11]

Fig. 11 is a schematic sectional view showing another modification of the liquid crystal display according to the second embodiment.

[Fig. 12]

Fig. 12 is a schematic sectional view showing another modification of the liquid crystal display according to the second embodiment.

[Fig. 13]

Fig. 13 is a sectional view of a substrate arranged on the back which is provided with TFTs.

[Fig. 14]

Fig. 14 is a schematic sectional view of a known transfective liquid crystal display having two retardation layers.

[Fig. 15]

Fig. 15 is a schematic sectional view of a known transfective liquid crystal display having four retardation

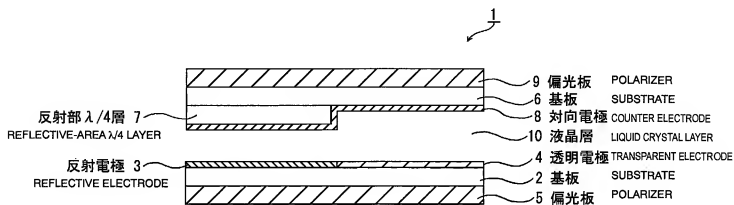
layers.

[Reference Numerals]

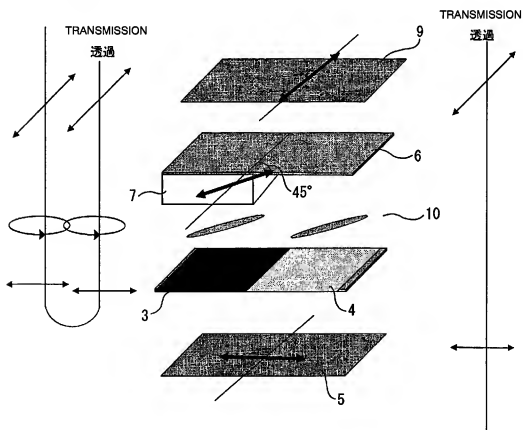
- 2: substrate
- 3: reflective electrode
- 4: transparent electrode
- 5: polarizer
- 6: substrate
- 7: reflective-area $\lambda/4$ layer
- 8: counter electrode
- 9: polarizer
- 10: liquid crystal layer

【書類名】 図面 [Name of Document] DRAWINGS

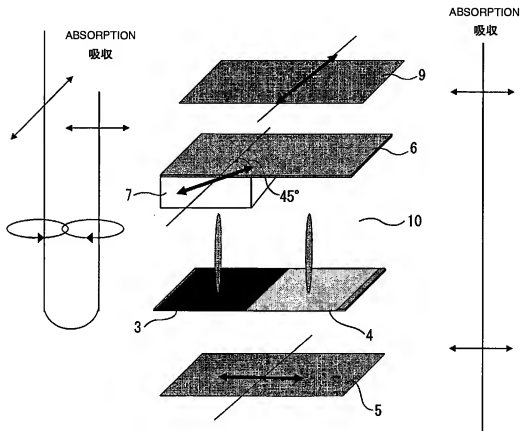
【図1】 [FIG. 1]



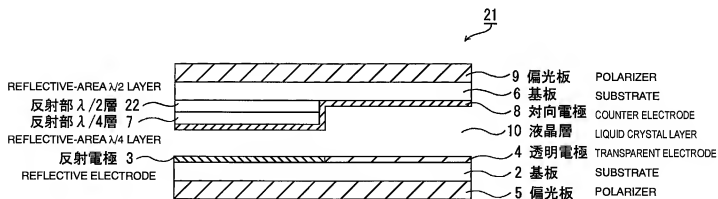
【図2】 [FIG. 2]



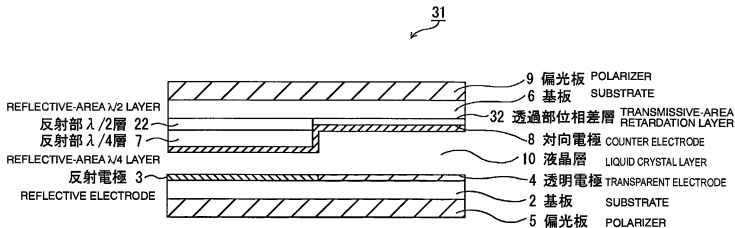
【図3】 [FIG. 3]



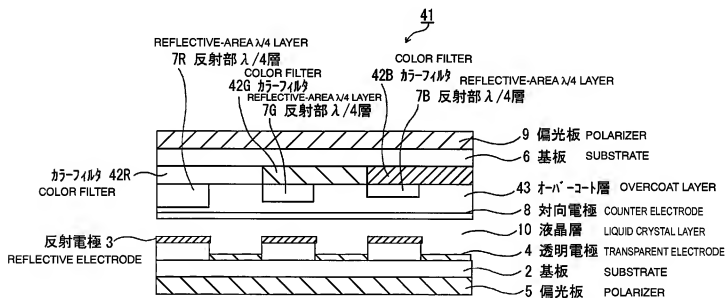
【図4】 [FIG. 4]



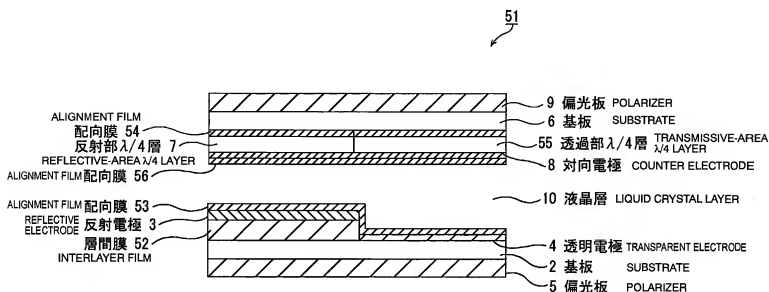
【図5】 [FIG. 5]



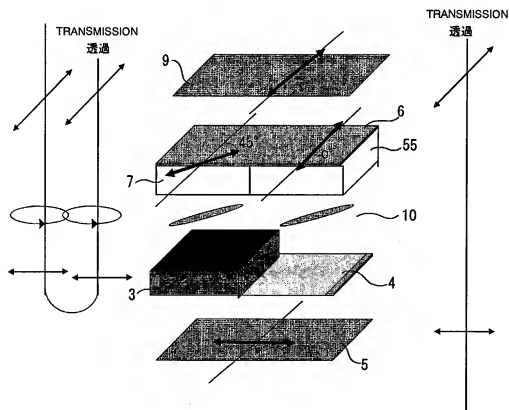
【図6】 [FIG. 6]



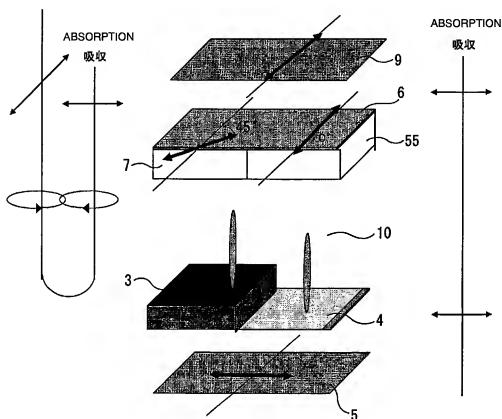
【図7】 [FIG. 7]



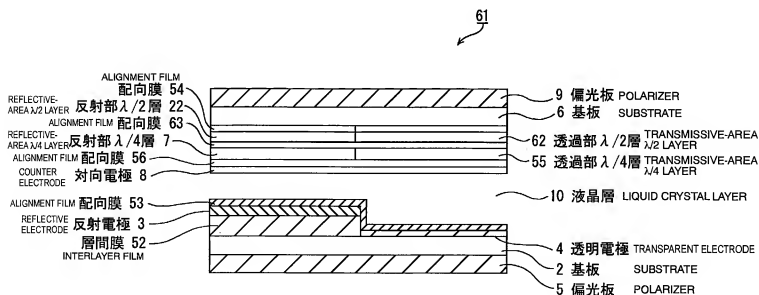
【図8】 [FIG. 8]



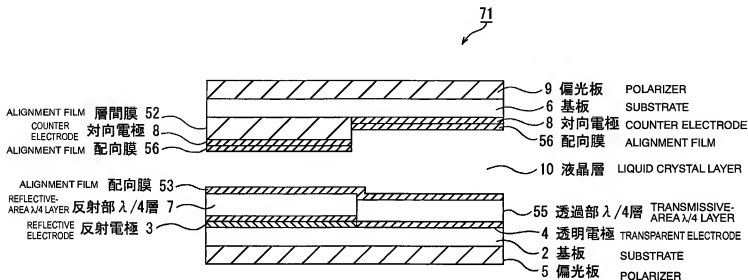
【図9】 [FIG. 9]



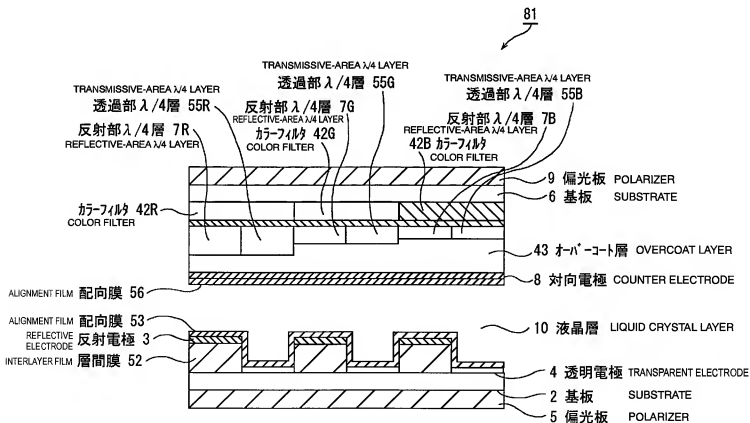
【図10】 [FIG. 10]



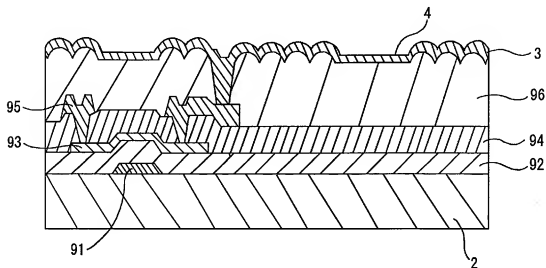
【図11】 [FIG. 11]



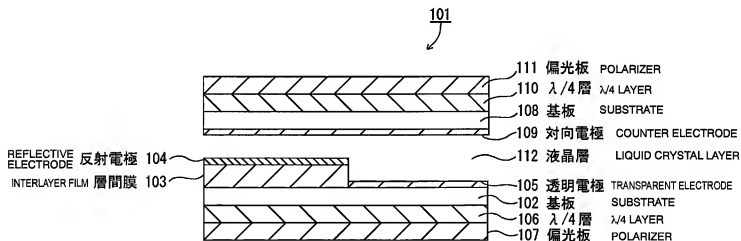
【図12】 [FIG. 12]



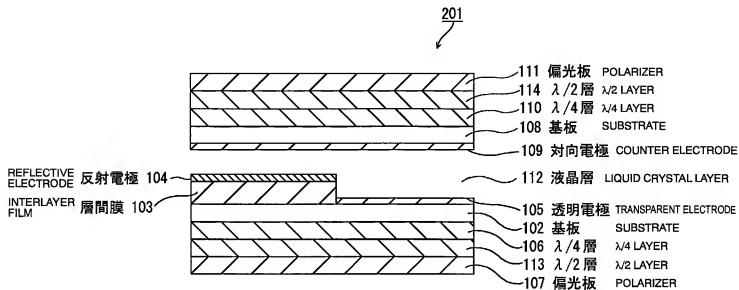
【図13】 [FIG. 13]



【図14】 [FIG. 14]



【図15】 [FIG. 15]



[Name of Document]

ABSTRACT

[Abstract]

[Object] To reduce the number of retardation layers to be disposed, for example, on the back of a transreflective liquid crystal display.

[Solving Means] A liquid crystal display includes a pair of substrates 2 and 6 and a liquid crystal layer 10 interposed between the substrates and has a reflective area 3 and a transmissive area 4. At least one of the substrates is provided with a retardation film 7 whose phase difference differs between the reflective area 3 and the transmissive area 4. Alternatively, a liquid crystal display includes a pair of substrates 2 and 6 and a liquid crystal layer 10 interposed between the substrates and has a reflective area 3 and a transmissive area 4, and at least one of the substrates is provided with a retardation film 7 whose slow axis differs between the reflective area 3 and the transmissive area 4.

[Selected Figure]

Fig. 1